DESCRIPTION

Signal Processing Method and Apparatus and Recording Medium

Technical Field

This invention relates to a signal processing method and apparatus and to a recording medium. More particularly, it relates to a signal processing method and apparatus and to a recording medium which takes the difference between the signals as detected by the sensor and the real world into account.

Background Art

Such a technique is widely exploited which detects events in the real world by sensors and which processes sampling data output by the sensors, such as data associated with pictures, speech, temperature, pressure, acceleration or odor.

For example, a picture obtained on imaging an object moving in front of a predetermined still background by a video camera is subjected to motion blurring in case the object is moved at a higher velocity.

For example, a picture obtained on imaging an object moving in front of a predetermined still background by a video camera employing a CCD is subjected to motion blurring in case the object is moved at a higher velocity. That is, when the real world is detected by a CCD as a sensor, the picture, as sampling data, undergoes distortion.

The conventional practice in suppressing this motion blurring is to increase the speed of e.g., an electronic shutter to provide for shorter light exposure time.

However, in raising the shutter speed in this manner, it is necessary to adjust the shutter speed of the video camera before proceeding to photographing. So, the blurred picture, previously acquired, cannot be corrected to obtain a clear picture.

On the other hand, if an object is moved in front of a stationary background, not only motion blurring due to mixing of no other than the picture of the moving object, but also the mixing of the background picture and the moving object occurs. In the conventional system, no consideration is given to detecting the mixing state of the background picture and the moving object.

Moreover, the information of the real world having the space and the time axis is acquired by a sensor and made into data. The data acquired by the sensor is the information obtained on projecting the information of the real world in the time and space of a lower dimension than the real world. So, the information obtained on projection is distorted due to projection. Stated differently, the data output by the sensor is distorted relative to the information of the real world. Moreover, the data, distorted by projection, also includes the significant information for correcting the distortion.

In the conventional signal processing on the sampling data, acquired by the sensor, the sampling data obtained by the sensor is deemed to be the most reliable data, such that, in subsequent data processing, such as transmission, recording or

reproduction, it has been a sole concern to realize the state of data which is as close to that of the original data as possible, in consideration of deterioration caused by e.g., data transmission.

Heretofore, the sampling data output by the sensor is deemed to be the most reliable data, such that no attempt has been made to prepare data higher in quality than the sampling data or to perform signal processing of extracting the significant information buried by projection.

Disclosure of the Invention

It is therefore an object of the present invention to provide for adjustment of the amount of motion blurring contained in detection signals of a blurred picture.

It is another object of the present invention to enable detection of a mixing ratio indicating the state of mixing of plural objects such as a background picture and a picture of a moving object.

It is yet another object of the present invention to provide a signal processing apparatus in which sampling data output by a sensor may be freed of distortion or the significant information can be extracted from the sampling data, for example, to provide for adjustment of the amount of motion blurring contained in the detection signal if the sampling data is that of picture.

The present invention provides a picture processing apparatus for processing picture data made up of a predetermined number of pixel data acquired by an imaging

device having a predetermined number of pixels each having an integrating effect, the picture processing apparatus including processing unit decision means for deciding, based on area information specifying a foreground area made up only of foreground object components making up a foreground object in the picture data, a background area made up only of background object components making up a background object in the picture data, and a mixed area which is a mixture of the foreground object components and the background object components in the picture data, the mixed area including a covered background area formed at a leading end in a movement direction of the foreground object, and an uncovered background area formed at a trailing end of the foreground object, a processing unit made up of pixel data lying on at least a straight line extending in a direction coincident with the direction of movement of the foreground object from an outer end of the covered background area to an outer end of the uncovered background area, centered about the foreground area, normal equation generating means for generating a normal equation by setting pixel values of pixels in the processing unit decided based on the processing unit and a dividing value which is an unknown dividing value obtained on dividing the foreground object components in the mixed area with a predetermined dividing number, and calculating means for solving the normal equation by the least square method to generate foreground object components adjusted for the quantity of movement blurring.

The present invention also provides a picture processing method for processing picture data made up of a predetermined number of pixel data acquired by an imaging

device having a predetermined number of pixels each having an integrating effect, the picture processing method including a processing unit decision step of deciding, based on area information specifying a foreground area made up only of foreground object components making up a foreground object in the picture data, a background area made up only of background object components making up a background object in the picture data, and a mixed area which is a mixture of the foreground object components and the background object components in the picture data, the mixed area including a covered background area formed at a leading end in a movement direction of the foreground object, and an uncovered background area formed at a trailing end of the foreground object, a processing unit made up of pixel data lying on at least a straight line extending in a direction coincident with the direction of movement of the foreground object from an outer end of the covered background area to an outer end of the uncovered background area, centered about the foreground area, a normal equation generating step of generating a normal equation by setting pixel values of pixels in the processing unit decided based on the processing unit and a dividing value which is an unknown dividing value obtained on dividing the foreground object components in the mixed area with a predetermined dividing number, and a calculating step of solving the normal equation by the least square method to generate foreground object components adjusted for the quantity of movement blurring.

The present invention also provides a picture processing program for processing picture data made up of a predetermined number of pixel data acquired by an imaging

device having a predetermined number of pixels each having an integrating effect, the picture processing program including a processing unit decision step of deciding, based on area information specifying a foreground area made up only of foreground object components making up a foreground object in the picture data, a background area made up only of background object components making up a background object in the picture data, and a mixed area which is a mixture of the foreground object components and the background object components in the picture data, the mixed area including a covered background area formed at a leading end in a movement direction of the foreground object, and an uncovered background area formed at a trailing end of the foreground object, a processing unit made up of pixel data lying on at least a straight line extending in a direction coincident with the direction of movement of the foreground object from an outer end of the covered background area to an outer end of the uncovered background area, centered about the foreground area, a normal equation generating step of generating a normal equation by setting pixel values of pixels in the processing unit decided based on the processing unit and a dividing value which is an unknown dividing value obtained on dividing the foreground object components in the mixed area with a predetermined dividing number and a calculating step of solving the normal equation by the least square method to generate foreground object components adjusted for the quantity of movement blurring.

The present invention also provides a signal processing apparatus for processing detection data, acquired every predetermined time period by a sensor made up of a

predetermined number of detection elements having time-integrating effects, every predetermined time period, the signal processing apparatus including foreground sample data extracting means for extracting the sample data present in detection data before or after considered detection data where there exists considered sample data which is the sample data under consideration, as foreground sample data corresponding to an object proving the foreground in the real world, background sample data extracting means for extracting the sample data present in detection data lying after or before the considered detection data where there exists considered sample data which is the sample data under consideration, as background sample data corresponding to an object proving the background in the real world and detection means for detecting a mixing ratio of the considered sample data based on the considered sample data, the foreground sample data and the background sample data.

The present invention also provides a signal processing method for processing detection data, acquired every predetermined time period by a sensor made up of a predetermined number of detection elements having time-integrating effects, every predetermined time period, the signal processing method including a foreground sample data extracting step of extracting the sample data present in detection data before or after considered detection data where there exists considered sample data which is the sample data under consideration, as foreground sample data corresponding to an object proving the foreground in the real world, a background sample data extracting step of extracting the sample data present in detection data

lying after or before the considered detection data where there exists considered sample data which is the sample data under consideration, as background sample data corresponding to an object proving the background in the real world and a detection step of detecting a mixing ratio of the considered sample data based on the considered sample data, the foreground sample data and the background sample data.

The present invention also provides a signal processing program for processing detection data, acquired every predetermined time period by a sensor made up of a predetermined number of detection elements having time-integrating effects, every predetermined time period, the signal processing program including a foreground sample data extracting step of extracting the sample data present in detection data before or after considered detection data where there exists considered sample data which is the sample data under consideration, as foreground sample data corresponding to an object proving the foreground in the real world, a background sample data extracting step of extracting the sample data present in detection data lying after or before the considered detection data where there exists considered sample data which is the sample data under consideration, as background sample data corresponding to an object proving the background in the real world and a detection step of detecting a mixing ratio of the considered sample data based on the considered sample data, the foreground sample data and the background sample data.

The present invention also provides a signal processing apparatus for processing detection data, acquired every predetermined time period by a sensor made up of a

predetermined number of detection elements having time-integrating effects, every predetermined time period, the signal processing apparatus including still/movement decision means for deciding still/movement based on the detection data, and detection means for detecting a mixed area containing sample data having plural real world objects mixed together based on the results of discrimination.

The present invention also provides a signal processing method for processing detection data, acquired every predetermined time period by a sensor made up of a predetermined number of detection elements having time-integrating effects, every predetermined time period, the signal processing method including a still/movement decision step of deciding still/movement based on the detection data, and a detection step of detecting a mixed area containing sample data having plural real world objects mixed together based on the results of discrimination.

The present invention also provides a signal processing program for processing detection data, acquired every predetermined time period by a sensor made up of a predetermined number of detection elements having time-integrating effects, every predetermined time period, the signal processing program including a still/movement decision step of deciding still/movement based on the detection data, and a detection step of detecting a mixed area containing sample data having plural real world objects mixed together based on the results of discrimination.

The present invention also provides a signal processing apparatus including means for acquiring second signals of a second dimension by projecting first signals

as real-world signals of a first dimension on a sensor and by detecting the mapped signals by the sensor, the first dimension being lower than the first dimension, and signal processing means for extracting the significant information, buried by the projection from the second signals, by performing signal processing which is based on the second signals.

The present invention also provides a recording medium having recorded thereon a computer-readable program, the program including a signal acquisition step of acquiring a second signal by projecting a first signal as a real world signal of a first dimension on a sensor and detecting the so-mapped first signal by the sensor, the signal being of a second dimension lower than the first dimension, and a signal processing step of performing signal processing based on the second signal to extract the significant information buried by projection from the second signal.

The present invention provides a signal processing apparatus including signal acquisition means for acquiring a second signal by detecting a first signal as a real world signal of a first dimension by a sensor, the signal being of a second dimension lower than the first dimension and containing distortion with respect to the first signal, and signal processing means for performing signal processing on the second signal for generating a third signal alleviated in distortion as compared to the second signal.

The present invention also provides a signal processing apparatus for processing a predetermined number of detection signals acquired by a sensor made up of a predetermined number of detection elements having time integrating effects, the signal

processing apparatus including area specifying means for specifying a foreground area made up only of foreground object components constituting an foreground object, a background area made up only of background object components constituting a background object, and a mixed area mixed from the foreground object components and the background object components, mixed area detection means for detecting a mixing ratio of the foreground object components and the background object components at least in the mixed area, and separating means for separating the foreground object and the background object from each other based on the specified results by the area specifying means and the mixing ratio.

The present invention also provides a signal processing method for processing a predetermined number of detection signals acquired by a sensor made up of a predetermined number of detection elements having time integrating effects, the signal processing method including an area specifying step of specifying a foreground area, made up only of foreground object components constituting an foreground object, a background area made up only of background object components constituting a background object, and a mixed area mixed from the foreground object components and the background object components, a mixed area detection step of detecting a mixing ratio of the foreground object components and the background object components at least in the mixed area, and a separating step of separating the foreground object and the background object from each other based on the specified results by the area specifying means and the mixing ratio.

The present invention also provides a recording medium having a computer-readable program, recorded thereon, the computer-readable program including an area specifying step of specifying a foreground area, made up only of foreground object components constituting an foreground object, a background area made up only of background object components constituting a background object, and a mixed area mixed from the foreground object components and the background object components, a mixed area detection step of detecting a mixing ratio of the foreground object components and the background object components at least in the mixed area and a separating step of separating the foreground object and the background object from each other based on the specified results by the area specifying means and the mixing ratio.

The present invention also provides a signal processing apparatus for processing a predetermined number of detection signals acquired by a sensor made up of a predetermined number of detection elements having time integrating effects, the signal processing apparatus including area specifying means for specifying a foreground area, made up only of foreground object components constituting an foreground object, a background area made up only of background object components constituting a background object, and a mixed area mixed from the foreground object components and the background object components, and mixing ratio detecting means for detecting a mixing ratio between the foreground object components and the background object components at least in the mixed area based on the results specified by the area

specifying means.

The present invention also provides a signal processing method for processing a predetermined number of detection signals acquired by a sensor made up of a predetermined number of detection elements having time integrating effects, the signal processing method including an area specifying step of specifying a foreground area, made up only of foreground object components constituting an foreground object, a background area made up only of background object components constituting a background object, and a mixed area mixed from the foreground object components and the background object components, and a mixing ratio detecting step of detecting a mixing ratio between the foreground object components and the background object components at least in the mixed area based on the results specified by the area specifying means.

The present invention also provides a recording medium having a computer-readable program recorded thereon, the signal processing method for processing a predetermined number of detection signals acquired by a sensor made up of a predetermined number of detection elements having time integrating effects, the computer-readable program including an area specifying step of specifying a foreground area, made up only of foreground object components constituting an foreground object, a background area made up only of background object components constituting a background object, and a mixed area mixed from the foreground object components and the background object component, and a mixing ratio detecting step

of detecting a mixing ratio between the foreground object components and the background object components at least n the mixed area based on the results specified by the area specifying means.

The present invention also provides a signal processing apparatus for processing a predetermined number of detection signals acquired by a sensor made up of a predetermined number of detection elements having time integrating effects, the signal processing apparatus including mixing ratio detecting means for detecting a mixing ratio of foreground object components and background object components in a mixed area in which said foreground object components constituting a foreground object and said background object components constituting a background object are mixed, and separating means for separating the foreground object and the background object from each other based on the mixing ratio.

The present invention provides a signal processing method for processing a predetermined number of detection signals acquired by a sensor made up of a predetermined number of detection elements having time integrating effects, the signal processing method including a mixing ratio detecting step of detecting a mixing ratio of foreground object components and background object components in a mixed area in which said foreground object components constituting a foreground object and said background object components constituting a background object are mixed, and a separating step of separating the foreground object and the background object from each other based on the mixing ratio.

The present invention also provides a recording medium having recorded thereon a computer-readable program for processing a predetermined number of detection signals acquired by a sensor made up of a predetermined number of detection elements having time integrating effects, the computer-readable program including a mixing ratio detecting step of detecting a mixing ratio of foreground object components and background object components in a mixed area in which said foreground object components constituting a foreground object and said background object components constituting a background object, and a separating step of separating the foreground object and the background object from each other based on the mixing ratio.

Brief Description of the Drawings

Fig.1 illustrates the principle of the present invention.

Fig.2 is a block diagram showing an illustrative structure of a system embodying the present invention.

Fig.3 is a block diagram showing an illustrative structure of a signal processor of Fig.2.

Fig.4 is a flowchart for illustrating the operation of the system of Fig.2.

Fig.5 illustrates a typical picture acquired at step S1 of Fig.4.

Fig.6 illustrates pixel values of a mixed area.

Fig.7 illustrates the result of subtracting picture components of the background

in domains D1 to D3 of Fig.6.

Fig.8 illustrates the structure of motion blurring.

Fig.9 is a flowchart for illustrating another typical processing of the system of Fig.2.

Fig.10 is a block diagram showing a signal processor 12.

Fig.11 illustrates the photographing by a sensor.

Fig.12 illustrates pixel arrangement.

Fig.13 illustrates the operation of a detection device.

Fig.14 illustrates a picture obtained on imaging an object corresponding to the moving foreground and an object corresponding to a stationary background.

Fig.15 illustrates a background area, a foreground area, a mixed area, a covered background area and an uncovered background area..

Fig.16 is a diagrammatic view showing pixel values of pixels arranged in a neighboring relation to another in a row in a picture obtained on imaging an object corresponding to the stationary foreground and a picture obtained on imaging an object corresponding to the stationary background, with the pixel values extended in the time axis direction.

Fig.17 is a diagrammatic view showing pixel values extended in the time axis direction, with the time period corresponding to the shutter time shown split.

Fig.18 is a diagrammatic view showing pixel values extended in the time axis direction, with the time period corresponding to the shutter time shown split.

Fig.19 is a diagrammatic view showing pixel values extended in the time axis direction, with the time period corresponding to the shutter time shown split.

Fig.20 shows extracted pixels of a foreground area, a background area and a mixed area.

Fig.21 shows the relation of correspondence between pixels and a model obtained on expanding the pixel values in the time axis direction.

Fig.22 is a diagrammatic view showing pixel values developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.23 is a diagrammatic view showing pixel values developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.24 is a diagrammatic view showing pixel values developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.25 is a diagrammatic view showing pixel values developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.26 is a diagrammatic view showing pixel values developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.27 is a flowchart for illustrating the processing for adjusting the amount of the motion blurring.

Fig.28 is a block diagram showing an illustrative structure of an area specifying unit 103.

Fig.29 illustrates a picture as an object corresponding to the foreground is being

moved.

Fig.30 is a diagrammatic view showing pixel values developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.31 is a diagrammatic view showing pixel values developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.32 is a diagrammatic view showing pixel values developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.33 illustrates a condition for areal decision.

Figs.34A, 34B, 34C and 34D illustrate the results of identification of areas of the area specifying unit 103.

Fig.35 illustrates the results of identification of areas of the area specifying unit 103.

Fig.36 is a flowchart for illustrating the processing for areal identification.

Fig.37 is a block diagram showing an illustrative structure of a mixing ratio calculating unit 104.

Fig.38 shows a typical ideal mixing ratio α.

Fig.39 is a diagrammatic view showing pixel values developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.40 is a diagrammatic view showing pixel values developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.41 illustrates the approximation exploiting the correlation of the foreground

components.

Fig.42 illustrates the relation between C, N and P.

Fig.43 is a block diagram showing the structure of an estimated mixing ratio processor 201.

Fig.44 shows a typical estimated mixing ratio.

Fig.45 is a block diagram showing a modified structure of the mixing ratio calculating unit 104 ..

Fig.46 is a flowchart for illustrating the processing for calculating the estimated mixing ratio.

Fig.47 is a flowchart for illustrating the processing for the operation of the estimated mixing ratio.

Fig.48 is a block diagram showing an illustrative structure of a foreground/background separating unit 105.

Figs.49A and 49B show an input picture, a foreground component picture and a background component picture.

Fig.50 is a diagrammatic view showing pixel values developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.51 is a diagrammatic view showing pixel values developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.52 is a diagrammatic view showing pixel values developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.53 is a block diagram showing an illustrative structure of a separator 251.

Figs.54A and 54B illustrate typical examples of a foreground component picture and a background component picture as separated from each other.

Fig.55 is a flowchart for illustrating the processing for separating the foreground and the background from each other.

Fig.56 is a block diagram showing an illustrative structure of a motion blurring adjustment unit 106.

Fig.57 illustrating a processing unit.

Fig.58 is a diagrammatic view showing pixel values of a foreground component picture developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.59 is a diagrammatic view showing pixel values of a foreground component picture developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.60 is a diagrammatic view showing pixel values of a foreground component picture developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.61 is a diagrammatic view showing pixel values of a foreground component picture developed in the time axis direction and showing the time period corresponding to the shutter period shown split.

Fig.62 shows a modified structure of the motion blurring adjustment unit 106.

Fig.63 is a flowchart for illustrating the processing for adjusting the amount of motion blurring contained in the foreground component picture

Fig.64 is a block diagram showing a modified structure of the function of a signal processor 12.

Fig.65 shows the structure of a synthesis unit 371.

Fig.66 is a block diagram showing another modified structure of the function of the signal processor 12.

Fig.67 is a block diagram showing the structure of a mixing ratio calculating unit 401.

Fig.68 is a block diagram showing the structure of a foreground/background separating unit 402.

Fig.69 is a block diagram showing a further modified structure of the function of the signal processor 12.

Fig.70 illustrates the structure of a synthesis unit 431.

Fig.71 shows another illustrative structure of a signal processing apparatus according to the present invention.

Fig.72 is a flowchart for illustrating the processing for adjusting the amount of motion blurring by a signal processor 452.

Fig.73 shows an illustrative structure of a signal processing apparatus according to the present invention.

Fig.74 shows a structure of a pressure area sensor 501.

Fig.75 illustrates the load applied to the pressure area sensor 501.

Fig.76 illustrates typical weight data output by the pressure area sensor 501.

Fig.77 is a flowchart for illustrating the load calculating processing executed by a signal processor 502.

Fig.78 is a block diagram showing the structure of generating a picture having an increased number of pixels per frame, as another function of the signal processor 12.

Fig.79 illustrates pixel arrangement and an area corresponding to a pixel doubled in horizontal density.

Fig.80 illustrates a picture component of a picture corresponding to light input to areas A to r.

Figs.81A, 81B, 81C and 81D illustrates calculation of picture components corresponding to two areas of a pixel.

Fig.82 shows a typical input picture.

Fig.83 shows a typical double horizontal density picture.

Fig.84 shows a typical double vertical density picture.

Fig.85 shows a double density picture.

Fig.86 is a flowchart for illustrating the processing for generating a double density picture by a signal processor 12 shown in Fig.78.

Best mode for Carrying out the Invention

Fig.1 shows the principle of the present invention. As may be seen in Fig.1, a first signal, as the information of a real world 1 having the spatial axis and the temporal axis, is acquired by a sensor 2, and is made into data. A detection signal, as data 3 acquired by the sensor 2, is the information obtained on projecting the information of the real world 1 on a time space of a lower dimension than in the real world 1. Therefore, the information, resulting from the projection, contains distortion ascribable to projection. Stated differently, the data 3, output by the sensor 2, is distorted relative to the information of the real world 1. Moreover, the data 3, thus distorted as a result of projection, also includes the significant information usable or correcting the distortion.

Thus, according to the present invention, the data output by the sensor 2 is processed by a signal processor 4, whereby the distortion is removed, reduced or adjusted. Alternatively, the data output by the sensor 2 is processed by the signal processor 4 to extract the significant information.

Fig.2 shows an illustrative structure of a signal processing apparatus according to the present invention The sensor 1 is comprised e.g., of a video camera, which photographs a picture of the real world to output the resulting picture data to the signal processor 12. The signal processor is comprised e.g., of a personal computer for processing the data input from the sensor 11, adjusting the amount of distortion produced by projection, specifying an area containing the significant information buried by the projection, extracting the significant information from a specified area

and for processing the input data based on the extracted significant information.

The significant information may, for example, be a mixing ratio, as later explained.

Meanwhile, the information indicating an area containing the significant information buried by the projection may also be deemed to be the significant information. Here, the areal information, as later explained, corresponds to the significant information.

The signal processor 12 is configured as shown for example in Fig.3. A CPU (central processing unit) 21 executes various processing operations in accordance with a program stored in a ROM (read-only memory) 22 or in a storage unit 28. In a RAM (random access memory) 23, the program executed by the CPU 21 or data are stored as necessary. The CPU 21, ROM 22 and the RAM 23 are interconnected over a bus 24.

To the CPU 21 is connected an input/output interface 25 over a bus 24. To the input/output interface 25 are connected an input unit 26, comprised of a keyboard, a mouse and a microphone, and an output unit 27, comprised of a display and a speaker. The CPU 21 executes various processing operations responsive to commands input from the input unit 26. The CPU 21 outputs a picture, speech and so forth, obtained on processing, to the output unit 27.

The storage unit 28, connected to the input/output interface 25, is constituted e.g., by a hard disc, for storing the program executed by the CPU 21 and a variety of

data. A communication unit 29 communicate with external equipment over a network, such as Internet. In the present embodiment, the communication unit 29 operates for acquiring an output of the sensor 11.

The program may also be acquired over the communication unit 29 for storage in the storage unit 28.

A driver 30 connected to the input/output interface 25 drives a magnetic disc 51, an optical disc 52, a magneto-optical disc 53 or a semiconductor memory 54, to acquire the program and data recorded therein, when these devices are connected thereto. The program and the data, thus acquired, are transferred to the storage unit 28, as necessary, for storage therein.

Referring to the flowchart of Fig.4, the operation performed by the signal processing apparatus based on the program stored in the storage unit 28, is explained. First, at step S1, a picture of an object, acquired by the sensor 11, is acquired through e.g., the communication unit 29. The CPU 21 of the signal processor 12 sends the acquired picture data to the storage unit 28 for storage therein.

Fig.5 shows a picture associated with the so-acquired picture data. The picture, shown in this embodiment, is comprised of a foreground 62 arranged ahead of a background 61. The foreground here is a toy plane moving at a predetermined speed ahead of the still background 61 towards right in the drawing. The result is that the picture of the foreground 62 is a picture subjected to so-called motion blurring. Conversely, the picture of the background 61 is stationary and hence is a clear picture

free of motion blurring. A mixed area 63 is a picture comprised of a mixture of an object which is the background 61 and an object which is the foreground 62.

Then, at step S2, the CPU 21 detects the mixed area of the objects. In the embodiment of Fig.5, the mixed area 63 is detected as an area of the mixture of the two objects.

The CPU 21 at step S3 decides whether or not the objects are mixed. If the objects are not mixed, that is if there is no mixed area 63, the picture is not what is to be processed by the present information processing apparatus and hence the processing is finished.

If conversely a decision is made at step S3 that the objects are mixed, the CPU 21 proceeds to step S4 to find the object mixing ratio in the detected mixed area. The mixing ratio may be found by finding the motion vector of the foreground 21 relative to the background 61 and by fitting, from the motion vector, so that the mixing ratio in the mixed area 63 will be changed in a range from 0 to 1. At step S5, the CPU 21 performs the processing of separating the objects in the mixed area 63 where plural objects are mixed together, based on the so-found mixing ratio.

The above-described processing is explained in further detail, taking a picture of Fig.5 as an example. If picture data on one line of a portion 63A on the right end of the mixed area 63 of Fig.5 is plotted, the result is as shown in Fig.6, in which the abscissa denotes X-coordinates (coordinates in the horizontal direction in Fig.5) and the ordinate denotes pixel values on the X-coordinates.

A curve L1 denotes pixel values on a line of a first timing, whilst a curve L2 denotes pixel values on another line of the next timing. Similarly, curves Light reflecting layer 3 and L4 denote pixel values of lines of the sequentially consecutive timings. Stated differently, Fig.6 shows changes in the pixel values on associated lines at the four consecutive timings.

The curve Li shows the state in the first timing in which state the foreground 62 has not yet been imaged. So, the curve L1 represents pixels of the foreground 61.

On the curve L1, the pixel value is approximately 75 in the vicinity of the X-coordinate 140, and is increased to approximately 130 at the X-coordinate 145. The pixel value then is lowered and is approximately 120 in the vicinity of the X-coordinate 149. As the X-coordinate is increased, the pixel value is again increased and reaches approximately 160 in the vicinity of the X-coordinate 154. The pixel value then is again lowered and reaches approximately 130 in the vicinity of the X-coordinate 162. Then, in the vicinity of the X-coordinate of 165, the pixel value is approximately 180 and, in the vicinity of the X-coordinate of 170, the pixel value is again lowered to approximately 125. Then, in the vicinity of the X-coordinate of 172, the pixel value is increased to approximately 175 and, in the vicinity of the X-coordinate of 178, the pixel value is lowered to approximately 60. Subsequently, the pixel value is slightly fluctuated between 60 and 80 in a domain of the X-coordinates of from 178 to 195. In the X-coordinates on the further right side of approximately 195, the pixel value is again increased to approximately 160.

As for the curve L2 of the next frame, the pixel value is constant at approximately 200 up to the pixel value of 145. The pixel value then is gradually lowered in a range from the X-coordinate of 145 to the Y-coordinate of 160, at which Y-coordinate value the pixel value is approximately 125. The curve then undergoes changes in a manner similar to those of the curve L1.

The pixel value of the curve Light reflecting layer 3 is substantially constant at 200 up to the vicinity of the X-coordinate 158 and is then lowered to approximately 164 at the X-coordinate 164, after which it is increased to approximately 190. The curve then undergoes changes in a manner similar to those of the curve L1.

The pixel value of the curve L4 is constant at approximately 200 from the vicinity of the X-coordinate of 140 up to the vicinity of the X-coordinate 170, and is abruptly lowered from the vicinity of the X-coordinate of 170 up to the vicinity of the X-coordinate 180, with the pixel value in the vicinity of the X-coordinate of 170 being approximately 70. The curve then undergoes changes in a manner similar to those of the curve L1.

These changes in the pixel values of the curves L2 to L4 are ascribable to the fact that, while the picture of only the background 61 exists in the state of the curve L1, the picture of the foreground 62 is gradually increased with the movement of the picture of the foreground 62, that is with lapse of time.

Specifically, as may be seen from comparison of the curve L1 and the curve L2 of the next following timing, the values of the curves L2 to L4 are substantially equal

in values up to the vicinity of the X-coordinate of 147. Beginning from the vicinity of the X-coordinate 147, the values of the curve L2 differ from those of the curves Light reflecting layer 3, L4,becoming equal to the values of the curve L1 in vicinity of the X-coordinate 159. Subsequently, the pixel values of the curve L2 are approximately equal to those in the curve L1. That is, the values of the curve L2 in an area R1 corresponding to a domain D1 from an X-coordinate 146 to an X-coordinate 159 indicate that the foremost part of the foreground 62 has been moved from the left end to the right end of the domain D1 during one unit period.

Similarly, the pixel values of the curve Light reflecting layer 3 of the next timing in an area Rigid substrate 2 corresponding to a domain D2 from an X-coordinate 159 to an X-coordinate 172 indicate that the foremost part of the foreground 62 has been moved in the interim. The pixel values of the curve L4 of the next timing in an area R3 corresponding to a domain D3 from the X-coordinate 172 to an X-coordinate 184 indicate that the foremost part of the foreground 62 has been moved in the interim.

So, if the pixel values of the curve L1, weighted on the basis of a mixing ratio of the foreground 62 to the background 61, are subtracted from the pixel values of the curve L2, a curve L11 shown in Fig.7 is obtained. This curve L11, tantamount to subtraction of the values corresponding to background 61 from the pixels of the foreground 62 in the mixed area 63, represents a picture of the foreground on the background having the pixel value of 0. Meanwhile, in Fig.7, the abscissa and the

ordinate denote the position and the pixel values of the extracted foreground, respectively. As for the position, the left and the right end correspond to the left and right ends in the domain D1 in Fig.6, respectively.

Similarly, if, in the domain D2 of Fig.6, the pixel values of the curve L1, weighted by the mixing ratio, are subtracted from the pixel values of the curve Light reflecting layer 3, a curve L12 in Fig.7 is obtained, whereas, if, in the domain D3 of Fig.6, the pixel values of the curve L1, weighted by the mixing ratio, are subtracted from the curve L4, a curve L13 in Fig.7 is obtained. The curves L12, L13 are substantially coincident with the curve L11, as shown in Fig.7. This indicates that the foreground 62 is moving at an approximately equal speed during the three timing unit periods, and that the black background, that is the foreground pixel values on the background having the pixel value of 0, has been obtained correctly by weighted subtraction.

If the above-described operation is explained in connection with pixels by referring to Fig.8, in which the abscissa denotes the X-coordinate of a portion 63A, with the ordinate denoting the time axis directing from above towards below. Since the amount of movement is 5 in the present embodiment, light exposure is made within the time interval of t1 to t5 (within the shutter time). In Fig.8, b1 to bf denote pixel values of the respective pixels of the background 61 and A1 to A6 denote pixel values of the foreground 62.

That is, the pixels A1 to A6 of the foreground 62 appear at the positions of the

pixels b3 to b8 of the background 61, with the pixels A1 to A6 of the foreground 62 moving rightwards at the timing t2 by one pixel, that is to the position of the pixels b4 to b9 of the background 61.

In similar manner, the pixels A1 to A6 of the foreground 62 are sequentially moved rightwards at a pitch of one pixel as time elapses from timing t3 to timing t5. In this case, the pixel values y1 to yf, obtained on averaging the pixels of the respective lines of the timings t1 to t5, constitute pixels obtained on imaging, that is pixels exhibiting motion blurring, with the values being represented by the following equations:

$$y_3 = \frac{1}{5} \cdot a_1 + \frac{4}{5} \cdot b_3 \quad \cdots (1)$$

$$y_4 = \frac{1}{5} \cdot (a_1 + a_2) + \frac{3}{5} \cdot b_4 \quad \cdots (2)$$

$$y_5 = \frac{1}{5} \cdot (a_1 + a_2 + a_3) + \frac{2}{5} \cdot b_5 \quad \cdots (3)$$

$$y_6 = \frac{1}{5} \cdot (a_1 + a_2 + a_3 + a_4) + \frac{1}{5} \cdot b_6 \quad \cdots (4)$$

$$y_7 = \frac{1}{5} \cdot (a_1 + a_2 + a_3 + a_4 + a_5) \quad \cdots (5)$$

$$y_8 = \frac{1}{5} \cdot (a_1 + a_2 + a_3 + a_4 + a_5 + a_6) \quad \cdots (6)$$

$$y_9 = \frac{1}{5} \cdot (a_3 + a_4 + a_5 + a_6) + \frac{1}{5} \cdot b_9 \quad \cdots (7)$$

$$y_a = \frac{1}{5} \cdot (a_4 + a_5 + a_6) + \frac{2}{5} \cdot b_a \quad \cdots (8)$$

$$y_b = \frac{1}{5} \cdot (a_5 + a_6) + \frac{3}{5} \cdot b_b \quad \cdots (9)$$

$$y_c = \frac{1}{5} \cdot a_6 + \frac{4}{5} \cdot b_c \quad \cdots (10)$$

Meanwhile, y1, y2, yd, ye and yf are equal to background pixels b1, b2, bd, be

and bf, respectively.

If pixels b1 to bf of the background are removed, the background 61 and the foreground 62 in the mixed area 63 can be separated from each other. That is, plural objects can be separated from one another. Moreover, the background pixels b1 to bf can be found by solving the above equations, using, for example, the least square method, by assuming the background pixels b1 to bf to be known such as by employing the pixel values of the fore and aft shutter time (frame). This gives a foreground picture freed of the motion blurring. In this manner, distortion caused by projection in the information of the real world can be reduced to create a clear picture such as by processing for resolution creation.

In Fig.4, it is the deterministic processing that is executed, that is, the previous processing is used as basis and the next following processing is executed on the assumption that the result of the previous processing is just. Alternatively, statistic processing is also possible, as now explained with reference to illustrative processing shown in Fig.9.

Specifically, when carrying out the statistic processing, the CPU 21 acquires picture data at step S21. This processing is similar to that performed at step S1 in Fig.4.

Next, st step S22, the CPU 21 performs the processing of finding the mixing ratio of the foreground an the background from the picture data obtained at step S21. At step S23, the CPU 21 executes the processing of separating the foreground and the

background based on the mixing ratio found at step S22.

If the statistic processing is used, the processing of deciding whether or not the boundary of an object exists, such as that at step S23 of Fig.4, is unnecessary, thus enabling the foreground and the background to be separated from each other more expeditiously.

The foregoing shows the manner as to how a clear picture of the foreground 62 can be separated and extracted from the motion-blurred picture obtained on photographing a picture of the foreground 62 moving ahead of the background 61.

A more specified embodiment of a signal processing apparatus for identifying an area having the significant information buried therein or extracting the so-buried significant information from data acquired from the sensor by the deterministic processing is now explained. In the following embodiment, a CCD line sensor or a CCR area sensor corresponds to the sensor, while the areal information or the mixing ratio corresponds to the significant information and the mixing of the foreground and the background or the motion blurring corresponds to distortion.

Fig.10 is a block diagram showing the signal processor 12.

Meanwhile, it does not matter whether the respective functions of the signal processor 12 are to be implemented by hardware or by software. That is, the block diagrams of the present specification may be deemed to be a hardware block diagram or a functional software block diagram.

It is noted that the motion blurring means distortion contained in a moving

object, which distortion is produced by the movement of an object in the real world being imaged and by imaging characteristics proper to the sensor 11.

In the present specification, the picture corresponding to an object in the real world is called a picture object.

An input picture, supplied to the signal processor 12, is furnished to an object extraction unit 101, an area specifying unit 103, a mixing ratio calculating unit 104 and a foreground background separating unit 105.

The object extraction unit 101 roughly extracts a picture object corresponding to a foreground object contained in the input picture to send the extracted picture object to a motion detection unit 102. The object extraction unit 101 detects the contour of the picture object corresponding to the foreground object contained in the input picture to roughly extract the picture object corresponding to the foreground object.

The object extraction unit 101 roughly extracts the picture object corresponding to the foreground object contained in the input picture to route the extracted picture object to the motion detection unit 102. The object extraction unit 101 roughly extracts the picture object corresponding to the background object, based on the difference between the input picture and the picture object corresponding to the extracted foreground object.

It is also possible for the object extraction unit 101 to roughly extract the picture object corresponding to the foreground object and the picture object

corresponding to the background object based on the difference between the background picture stored in an internal background memory and the input picture.

The motion detection unit 102 computes the motion vector of the picture object corresponding to the roughly extracted foreground,. by techniques such as block matching method, gradient method, phase correlation method or the Pel-Recursive method, to route the motion vector so calculated and the position information of the motion vector (the information specifying the position of the pixel corresponding to the motion vector) to the motion blurring adjustment unit 106.

In the motion vector, output by the motion detection unit 102, there is contained the information corresponding to a movement quantity v.

It is also possible for the motion detection unit 102 to output the picture object based motion vector, along with the pixel position information specifying the pixels for the picture object, to the motion blurring adjustment unit 106.

The movement quantity v is a value for representing position changes of picture corresponding to a moving object in terms of a pixel-to-pixel interval as unit. For example, if a picture of an object corresponding to the foreground is moved so as to be displayed at a position offset by four pixels in a frame with respect to a directly previous frame, the movement quantity v of the object corresponding to the foreground is 4.

Meanwhile, the object extraction unit 101 and the motion detection unit 102 are used when the quantity of the motion blurring associated with a moving object is

adjusted in the motion blurring adjustment unit 106.

The area specifying unit 103 sends the information specifying each pixel of an input picture to one of the foreground area, a background area or a mixed area and for indicating to which of the foreground area, background area and the mixed area belong the pixels, from pixel to pixel, to the mixing ratio calculating unit 104, foreground/background separating unit 105 and to the motion blurring adjustment unit 106. The aforementioned information is referred to below as the area information.

The mixing ratio calculating unit 104 calculates the mixing ratio for pixels contained in the mixed area 63, based on the input picture and the area information supplied from the area specifying unit 103, to route the so-calculated mixing ratio to the foreground/background separating unit 105. This mixing ratio is referred to below as a mixing ratio α.

The mixing ratio α indicates the proportion in the pixel value of the components of a picture corresponding to the background object, as indicated by an equation (13) to be described later. These components are also referred to below as the background components.

The foreground/background separating unit 105 separates the input picture into a foreground component picture, made up only of a picture component associated with the foreground, also referred to below as foreground components, and a background component picture, composed only of background components, based on the area information supplied from the area specifying unit 103, and on the mixing ratio α

supplied from the mixing ratio calculating unit 104, to route the foreground component picture to the motion blurring adjustment unit 106 and to the selection unit 107. The separated foreground component picture may also be an ultimate output. It is possible to realize the foreground and the background more accurate than those obtained in the conventional system in which only the foreground and the background can be specified without taking the conventional mixed area into consideration.

The motion blurring adjustment unit 106 decides a processing unit, indicating one or more pixels contained in the foreground component picture, based on the movement quantity v as found from the motion vector and on the area information. The processing unit is data for specifying a set of pixels to be processed for adjusting the quantity of the motion blurring.

The motion blurring adjustment unit 106 adjusts the quantity of the motion blurring contained in the foreground component picture, such as by removing the motion blurring contained in the foreground component picture, decreasing the quantity of the motion blurring or increasing the quantity of the motion blurring, based on the motion blurring adjusting quantity input to the signal processor 12, foreground component picture supplied from the foreground/background separating unit 105, the motion vector supplied from the motion detection unit 102, along with the corresponding position information, and on the processing unit, to output the foreground component picture, adjusted for the quantity of the motion blurring, to the selection unit 107. The motion vector with its position information may not be used,

if so desired.

The selection unit 107 selects one of the foreground component picture supplied from the foreground/background separating unit 105 and the foreground component picture from the motion blurring adjustment unit 106, adjusted as to the motion blurring quantity, to output the selected foreground component picture.

Referring to Figs.11 to 26, an input picture sent to the signal processor 12 is explained.

Fig.11 illustrates imaging by a sensor 11 constituted by a CCD video camera provided with a CCD (charge coupled device) which is a solid state imaging device. An object corresponding to the foreground in the real world is moved between the object of the background in the real world an the sensor 11 e.g., horizontally from left to right.

The sensor 11 images an object corresponding to the foreground along with the object corresponding to the background. The sensor 11 outputs the photographed picture on the frame basis. For example, the sensor 11 outputs a picture of 30 frames per sec. The exposure time of the sensor 11 may be set to 1/30 sec. The exposure time is the time which elapses since the start of conversion of light input to the sensor 11 into electrical charges until the end of the conversion of the input light into electrical charges. This exposure time is sometimes referred to below as the shutter time.

Referring to Fig.12, showing pixel arrangement, A to I denote individual pixels. The pixels are arranged in a plane corresponding to a picture. A detection element

associated with one pixel is arranged on the sensor 11. When the sensor 11 photographs a picture, one detection element outputs a pixel value associated with one pixel belonging to the picture. For example, the position of the detection device along the X-direction corresponds to the position on the picture in the transverse direction, whilst that along the Y-direction corresponds to the position on the picture in the longitudinal direction.

Referring to Fig.13, a detection device, such as the CCD, converts the input light into electrical charges, during the time corresponding to the shutter time, to store the as-converted electrical charges. The quantity of the electrical charges is approximately equal to the intensity of the input light and to the time during which the light is input. The detection device sums the electrical charges, converted from the input light, to the electrical charges, already stored, during the time corresponding to the shutter time. That is, the detection device integrates the input light during the time corresponding to the shutter time to accumulate electrical charges in an amount corresponding to the integrated light. The detection device is said to have an integrating effect with respect to time.

The charges accumulated in the detection device are converted into an electrical voltage by a circuit, not shown. The voltage, in turn, is converted into a pixel value, such as digital data, which is output. So, the individual pixels, output by the sensor 11, are of a value mapped to a one-dimensional space, which is the result of integration with respect to the shutter time of a spatially extended portion of an object

corresponding to the foreground or the background.

By such accumulating operation of the sensor 11, the signal processor 12 extracts the significant information buried in the output signal, such as the mixing ratio α. The signal processor 12 adjusts the quantity of distortion caused by the mixing of no other than the foreground picture object, for example, the quantity of the motion blurring. The signal processor 12 also adjusts the quantity of the distortion produced by the mixing of the foreground picture object with the background picture object.

Fig.14 illustrates a picture obtained on imaging an object corresponding to a moving foreground and an object corresponding to a still background. Fig.14A shows a picture obtained on imaging an object corresponding to the moving foreground and an object corresponding to the still background. In an embodiment shown in Fig.14A, the object corresponding to the foreground is moving horizontally from left towards right relative to the picture.

Fig.14B is a diagrammatic view showing pixel values, corresponding to a line of the picture shown in Fig.14A, as extended along the time axis. The transverse direction of Fig.14B corresponds to the spatial direction X of Fig.14A.

The pixels of the background area are constituted solely by the background components, that is components of a picture corresponding to a background object. The pixels of the foreground area are constituted solely by the foreground components, that is components of a picture corresponding to a foreground.

The pixels of the mixed area are constituted from the background and

foreground components. The mixed area, the pixel values of which are constituted from the background components and the foreground components, may be said to be a distorted area. The mixed area is further classified into a covered background area and an uncovered background area.

The covered background area is a portion of the mixed area in register with the foremost part along the proceeding direction of the foreground and is an area in which the background component is hidden by the foreground with lapse of time.

On the other hand, the uncovered background area is a portion of the mixed area in register with the rear part along the proceeding direction of the foreground and is an area in which the background component presents itself with lapse of time.

A picture comprised of the foreground area, background area, a covered background area or the uncovered background area is input as an input picture to the area specifying unit 103, mixing ratio calculating unit 104 and to the foreground/background separating unit 105.

Fig.15 illustrates the background area, foreground area, mixed area, covered background area and the uncovered background area, as described above. In relation to the picture shown in Fig.14, the background area is a still portion, the foreground area is a moving portion, the covered background area of the mixed area is an area where the picture is changed from the background to the foreground, and the uncovered background area of the mixed area is an area where the picture is changed from the foreground to the background.

Fig.16 diagrammatically shows pixel values of neighboring pixels in a row in a photographed picture of an object corresponding to a still foreground and an object corresponding to a sill background, with the pixel values shown developed along the temporal axis direction. As the neighboring pixels, arranged in a row, it is possible to select pixels arranged on a line of a picture.

The pixel values of F01 to F04, shown in Fig.16, are those of pixels of the object of the still foreground. The pixel values of B01 to B04, shown in Fig.16, are those of pixels of the object of the still background.

In Fig.16, time elapses from above towards below. The position of an upper side of a rectangle in Fig.16 corresponds to the time the sensor 11 begins converting the input light into electrical charges, while that of the rectangle in Fig.16 corresponds to the time the sensor 11 finishes the conversion of the input light into electrical charges. That is, the distance from the upper to the lower sides of the rectangle of Fig.16 corresponds to the shutter time.

In the following description, it is assumed that the shutter time is equal to the frame interval.

The transverse direction in Fig.16 corresponds to the spatial direction X, explained with reference to Fig.14. More specifically, the distance from the left side of a rectangle "F01" to the right side of a rectangle "B04" in Fig.16 is eight times the pixel pitch, that is the span of the eight consecutive pixels.

If the foreground and the background object are still, the light input to the

sensor 11 is not changed during the time corresponding to the shutter time.

The time span corresponding to the shutter time is split into two or more equal time periods. For example, if the number of times of the virtual splitting is four, the diagram of Fig.16 may be represented as the diagram of Fig.17. The number of times of the virtual splitting is set in association with e.g., the movement quantity v in the shutter time of the object corresponding to the foreground. For example, if the movement quantity v is four, the number of times of the virtual splitting is 4, with the time span corresponding to the shutter time being then split into four.

The uppermost row in the drawing corresponds to the first split time period since the time of shutter opening. The second row corresponds to the second split time period since the time of shutter opening. The third row corresponds to the third split time period since the time of shutter opening, whilst the fourth row corresponds to the fourth split time period since the time of shutter opening.

The shutter rime split in association with the movement quantity v is also called the shutter time/v hereinbelow.

When the object corresponding to the foreground is at a standstill, the light input to the sensor 11 is not changed. So, the foreground component F01/v is equal to the pixel value F01 divided by the number of times of the virtual splitting. Similarly, when the object corresponding to the foreground is at a standstill, the foreground component F02/v is equal to the pixel value F02 divided by the number of times of the virtual splitting, whilst the foreground component F03/v is equal to the

pixel value F03 divided by the number of times of the virtual splitting and the foreground component F04/v is equal to the pixel value F04 divided by the number of times of the virtual splitting.

When the object corresponding to the background is at a standstill, the light incident on the sensor 11 is not changed. So, the background component B01/v is equal to the pixel value B01 divided by the number of times of the virtual splitting. Similarly, when the object corresponding to the background is at a standstill, the background component B02/v is equal to the pixel value B02 divided by the number of times of the virtual splitting, whilst the background component B03/v is equal to the pixel value B03 divided by the number of times of the virtual splitting and the background component B04/v is equal to the pixel value B04 divided by the number of times of the virtual splitting.

That is, when the object corresponding to the foreground is at a standstill, the light corresponding to the foreground input to the sensor 11 during the time corresponding to the shutter time remains unchanged. So, the first foreground component F01v, corresponding to the shutter time/v, as from the shutter opening, the second foreground component F01v, corresponding to the shutter time/v, as from the shutter opening, the third foreground component F01v, corresponding to the shutter time/v, as from the shutter opening and the fourth foreground component F01v, corresponding to the shutter time/v, as from the shutter opening, are of equal values. The above for F01/v holds for F02/v to F04/v as well.

When the object corresponding to the background is at a standstill, the light corresponding to the background object input to the sensor 11 during the time corresponding to the shutter time remains unchanged. So, the first background component B01v, corresponding to the shutter time/v, as from the shutter opening, the second background component B01v, corresponding to the shutter time/v, as from the shutter opening, the third background component B01v, corresponding to the shutter time/v, as from the shutter opening and the fourth background component B01v, corresponding to the shutter time/v, as from the shutter opening, are of equal values. The above for B01/v holds for B02/v to B04/v as well.

In the following description, it is assumed that the object corresponding to the foreground is moving, with the object corresponding to the background being at a standstill.

Fig.18 diagrammatically shows pixel values of pixels arranged on a line including the covered background area when the object corresponding to the foreground is moving towards right in the drawing, with the pixel values being shown developed in the time axis direction. In Fig.18, the movement quantity v of the foreground is 4. Since one frame is of short duration, it may be assumed that the object corresponding to the foreground is a rigid body and moving at an equal speed. In Fig.18, the picture of the object corresponding to the foreground is moved so as to be displayed four pixels rightwards in a frame next to a directly previous reference frame.

In Fig.18, the leftmost to fourth left pixels belong to the foreground area. In Fig.18, fifth left to seventh left pixels in Fig.18 belong to the mixed area which is the covered background area. In Fig.18, the rightmost pixel belongs to the background area.

Since the object corresponding to the foreground is moved to hide the object corresponding to the background, as time elapses, the components contained in the pixel values of the pixels belonging to the covered background area are switched from the background component picture to the foreground component picture at a certain time point of the time period corresponding to the shutter time.

For example, the pixel value M, shown with a bold line frame in Fig.18, is represented by the equation (11):

$$M = B02/v + B02/v + F07/v + F06/v \qquad \cdots(11).$$

For example, the pixel value M, shown with a bold line frame in Fig.18, contains the background component corresponding to one shutter time/v and the foreground component corresponding to three shutter time/v, the mixing ratio α of the fifth left pixel is 1/4. The sixth left pixel contains the background component corresponding to two shutter time/v and the foreground component corresponding to two shutter time/v, so the mixing ratio α is 1/2. The seventh left pixel contains the background component corresponding to three shutter time/v and the foreground component corresponding to one shutter time/v, so the mixing ratio α is 3/4.

Since the object corresponding to the foreground is a rigid body, such that the foreground picture is moved at an equal speed so as to be displayed four pixels towards right in the next frame, the first foreground component F07/v of the fourth left pixel in Fig.18, with the first shutter time/v since the time of shutter opening, is equal to the second foreground component of the fifth left pixel in Fig.18 corresponding to the second shutter time/v since the time of shutter opening. Similarly, the foreground component F07/v is equal to the foreground component of the sixth left pixel in Fig.18 corresponding to the third shutter time/v since the time of shutter opening and to the foreground component of the seventh left pixel in Fig.18 corresponding to the fourth shutter time/v since the time of shutter opening.

Since the object corresponding to the foreground is a rigid body, such that the foreground picture is moved at an equal speed so as to be displayed four pixels towards right in the next frame, the first foreground component F06/v of the third left pixel in Fig.18, with the first shutter time/v since the time of shutter opening, is equal to the second foreground component of the fourth left pixel in Fig.18 corresponding to the second shutter time/v since the time of shutter opening. Similarly, the foreground component F06/v is equal to the foreground component of the fifth left pixel in Fig.18 corresponding to the third shutter time/v since the time of shutter opening and to the foreground component of the sixth left pixel in Fig.18 corresponding to the fourth shutter time/v since the time of shutter opening.

Since the object corresponding to the foreground is a rigid body, such that the

foreground picture is moved at an equal speed so as to be displayed four pixels towards right in the next frame, the first foreground component F05/v of the second left pixel in Fig.18, with the first shutter time/v since the time of shutter opening, is equal to the third foreground component of the fourth left pixel in Fig.18 corresponding to the second shutter time/v since the time of shutter opening. Similarly, the foreground component F05/v is equal to the foreground component of the fourth left pixel in Fig.18 corresponding to the third shutter time/v since the time of shutter opening and to the foreground component of the fifth left pixel in Fig.18 corresponding to the fourth shutter time/v since the time of shutter opening.

Since the object corresponding to the foreground is a rigid body, such that the foreground picture is moved at an equal speed so as to be displayed four pixels towards right in the next frame, the first foreground component F04/v of the leftmost pixel in Fig.18, with the first shutter time/v since the time of shutter opening, is equal to the second foreground component of the second left pixel in Fig.18 corresponding to the second shutter time/v since the time of shutter opening. Similarly, the foreground component F04/v is equal to the foreground component of the third left pixel in Fig.18 corresponding to the third shutter time/v since the time of shutter opening and to the foreground component of the fourth left pixel in Fig.18 corresponding to the fourth shutter time/v since the time of shutter opening.

The foreground area corresponding to the moving object thus contains the motion blurring and hence may be said to be a distorted area.

Fig.19 diagrammatically shows pixel values of pixels on a line comprehending the uncovered background area in case the foreground is moving towards right in the drawing, with the pixels shown extended in the time axis direction. In Fig.19, the movement quantity v of the foreground is 4. Since one frame is of short duration, it may be assumed that the object corresponding to the foreground is a rigid body and moving at an equal speed. In Fig.19, the picture of the object corresponding to the foreground is moved so as to be displayed four pixels rightwards in a frame next to a directly previous frame.

In Fig.19, the leftmost to fourth left pixels belong to the background area. In Fig.19, fifth left to seventh left pixels belong to the mixed area which is the covered background area. In Fig.19, the rightmost pixel belongs to the background area.

Since the object corresponding to the foreground which has hidden the object corresponding to the background is moved so as to be removed from a position ahead of the object corresponding to the background, as time elapses, the components contained in the pixel values of the pixels belonging to the covered background area are switched from the background component picture to the foreground component picture at a certain time point of the time period corresponding to the shutter time.

For example, the pixel value M', shown with a bold line frame in Fig.18, is represented by the equation (12):

$$M' = F02/v + F01/v + B26/v + B26/v \qquad \cdots (12).$$

For example, the fifth left pixel contains the background component corresponding to three shutter time/v and the foreground component corresponding to one shutter time/v, the mixing ratio α of the fifth left pixel is 3/4. The sixth left pixel contains the background component corresponding to two shutter time/v and the foreground component corresponding to two shutter time/v, so the mixing ratio α is 1/2. The seventh left pixel contains the background component corresponding to one shutter time/v and the foreground component corresponding to three shutter time/v, so the mixing ratio α is 1/4.

56.

If the equations (11), (12) are generalized, the pixel value M is represented by the following equation (13):

$$M = \alpha \cdot \beta + \sum_i Fi / v \qquad \cdots (13)$$

where α is a mixing ratio, B is a pixel value of the background and Fi/v is the foreground component.

Since the object corresponding to the foreground is a rigid body and may be assumed to be moving at an equal speed, with the movement quantity v being 4, the first foreground component F01/v of the fifth left pixel in Fig.19, with the first shutter time/v since the time of shutter opening, is equal to the second foreground component of the sixth left pixel in Fig.19 corresponding to the second shutter time/v since the time of shutter opening. Similarly, the F01/v is equal to the foreground component of